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Influence of Humidity Environment on the Fracture Energy of Cement Paste

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Abstract: Influence of humidity environment on the fracture energy of cement paste. Paper describes experimental investigation on the field of material properties of cement paste, especially fracture energy. Introduction is focused on preparation of cement paste specimens. In the experimental part is described system of testing of the specimens. Part results and observed properties is focused on the evaluation of data of measuring. Main concentration is focused on the differences between water dried and saturated specimens and their results. The differences between w/c ratios and sizes of specimens are discussed too. Influence of humidity environment on the fracture energy of cement paste is discussed in summary.

Keywords: Fracture energy, Compression stress, Cement paste, Three point bend test

1. Introduction

The mechanical behaviour is influenced by the materials used. Most of engineering materials is possible categorized into brittle, ductile, or quasi-brittle materials [1], [5]. The fracture energy is one of properties of the material, which is possible measuring by relatively simple method. This property described capability of the material resist to loading.

The cement paste is material based only on two parts; water and cement. Properties of cement pastes are relatively well known. Particular, the compressive strength depends on the water/cement ratio w/c. Equally, an important factor for compressive strength, the water content in the material. Increasing the amount of water in cement paste allows the maturation of the paste. The water content in the long term has a positive effect on the strength of cement paste.

Experiments described in the article investigated the influence of humidity of cement paste to the size of the fracture energy [6].

2. Preparing specimens

The advantage of the cement paste is the homogeneity. Homogeneous fine-grained materials are suitable for testing in smaller testing equipments. Therefore, the preparation of specimens was selected type of form 20 x 20 x 100 mm.

Portland cement CEM I 42,5 R was used for production of specimens. Because the intention was not to use a plasticizer, were selected water-cement ratio 0.35, 0.4 and 0.45. Grout with a water/cement ratio beyond the specified limit has high fluidity, which may cause segregation of cement and water. On the other hand, the grout may be too rigid and treated by

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practically no plasticizer. Consistency of 0.4 was chosen as a tougher type of cement paste. Conversely, thinner type of cement paste was defined by w/c ratio of 0.45. Specimens of cement paste was stored in the water basin for abouth 30 days.

The specimens were removed from the water two days before testing. Subsequently, specimens were dried for 48 hours at 60 °C. During the drying was to reduce weight to a saturated samples from 11 to 12 %, see Table 1.

Table 1. Specimens' weight lost on drying 2 days

w/c	*Weight (grams) Saturated*	*Weight (grams) Dried*	*Lost of weight (grams)*	*Lost of weight (%)*	*Mass density (kg/m^3) Saturated specimens*	*Mass density (kg/m^3) Dried specimens*
0.35	82.59	73.54	9.05	10.9	2072	1862
0.4	78.04	68.54	9.5	12.2	1965	1737
0.45	76.23	66.74	9.49	12.4	1948	1635

Before the start of testing at each specimens was cut notch about 7mm deep. The width of the notch specimens was 1 mm. Synoptic information is the mass density of cement paste for the water/cement ratios. Increasing the value of the water/cement ratio causes a reduction in the value of mass density.

Feature testing was performed on 6 specimens in each group. The group formed a designated water/cement ratio. Sets of dried specimens contained only 5 specimens. A total of 33 specimens tested.

3. Preparing tests

Execution of experiments was carried out in the test machine MTS Alliance RT 30kN. It is an electromechanical testing machine with a very subtle shift in the crosshead. By using relatively small specimens can achieve the desired results the test method. The size of test specimens and stiffness are two important parameters for achieving good results. If the stiffness of the testing machine is too small and the large size of specimen on the contrary there is a snapback or only achieve the maximum load, without softening the material is measured [2].

Fracture energy was measured in the tests performed using the three-point bending test (Fig. 1). Distance support the specimen was 80 mm. The notch was located in the middle of the range below the point where the applied load. To assessment the test were required two parameters, strength and vertical deflection of the specimen. For those of parameters it is possible to calculate the fracture energy of the test specimen. Before the tests were measured dimensions of each specimen.

The RILEM Technical Committee 50-FMC on Fracture Mechanics of Concrete – Test Method proposed a draft recommendation to measure the material fracture energy G_f using a three-point bend beam. Fracture energy is calculated on the basis of relation Eq. (1) [3].

$$G_f = \frac{W}{b \cdot (d - a)} \tag{1}$$

Where: G_f is fracture energy; w is total fracture energy; b is width of the specimen; d is height of the specimen and a is notch size. The energy absorbed by the beam is represented by

Fig. 1. Specimen in bend test

the area under the load – displacement curve P – δ curve, where δ is the load point displacement [4].The total area under P – δ curve is referred to as W, which may be divided into three parts, W_0, W_1, and W_2 Eq. (2).

$$W = W_0 + 2P_W\delta_0 = W_0 + W_1 + W_2 \tag{2}$$

W_0 is area below the measured P - δ curve. W_1 is $P_W\delta_0$. Both values W_1 and W_2 can be determined from measured P – δ curve. Peterson, Swartz and Yap demonstrated that value W_1 is approximately equal to the value of W_2. P_W - additional equivalent force is value which may be represented by influence of self-weight.

4. Results of specimens testing

The data obtained from tests carried out are summarized in graphs. One of the typical working diagram is shown in Fig. 2. The descending branch of the diagram is captured 95% decrease in strength to the maximum achieved value.

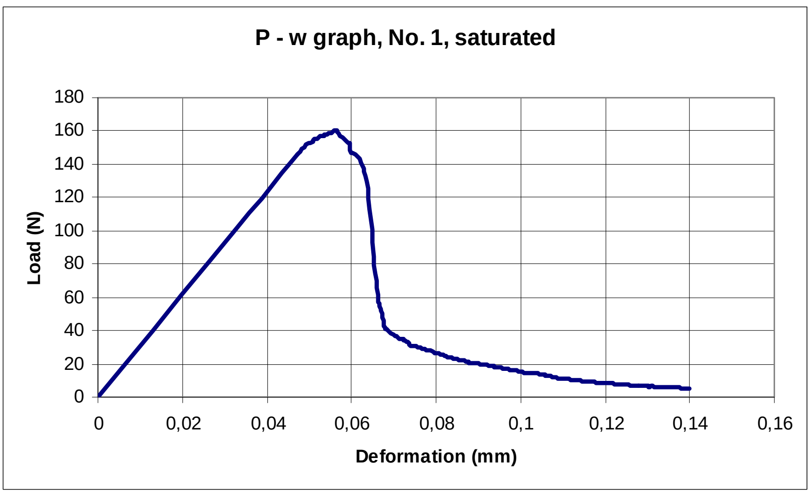

Fig. 2. Load – deformation graph, specimen No. 1, w/c ratio 0.35, saturated

The resulting graphs are shown in Fig. 3 to 8. Pictures are sorted by categories of water/cement ratio and by water saturation of specimens.

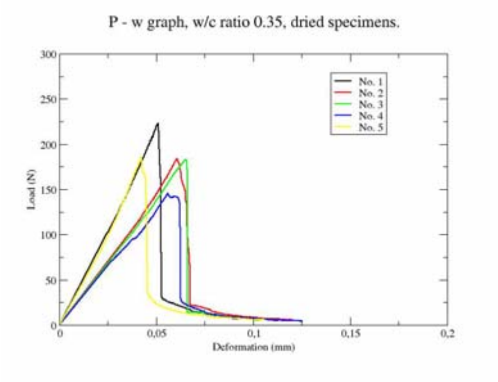

Fig. 3. P – δ graphs of water dried specimens prepared using w/c 0.35

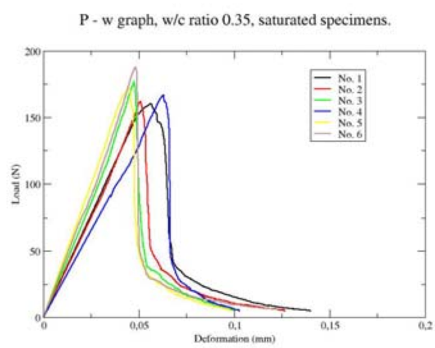

Fig. 4. P – δ graphs of water saturated specimens prepared using w/c 0.35

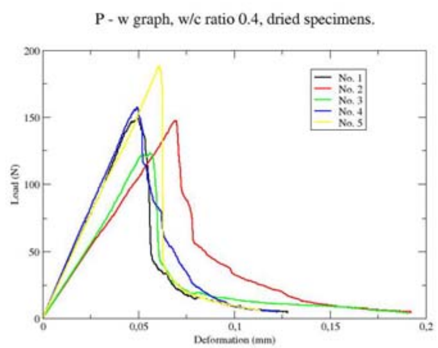

Fig. 5. P – δ graphs of water dried specimens prepared using w/c 0.4

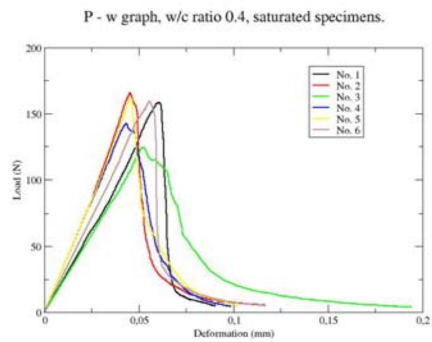

Fig. 6. P – δ graphs of water saturated specimens prepared using w/c 0.4

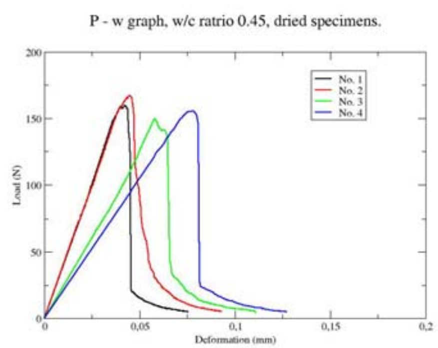

Fig. 7. P – δ graphs of water dried specimens prepared using w/c 0.45

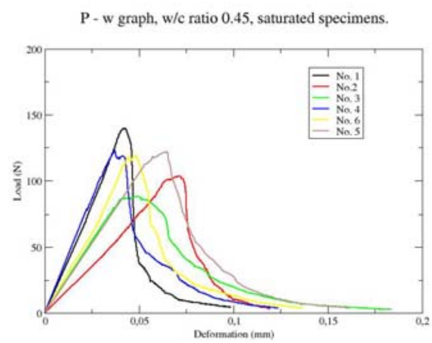

Fig. 8. P – δ graphs of water saturated specimens prepared using w/c 0.45

Table 2 shows the change of fracture energy for changing the water/cement ratio. Increasing water/cement ratio causes a decrease in fracture energy.

Table 2. Fracture energy and tensile strength in bending of cement paste

w/c	*Fracture energy (N/mm) Saturated specimens*	*Fracture energy (N/mm) Dried specimens*	*Tensile strength in bending, Saturated specimens*	*Tensile strength in bending, Dried specimens*
0.35	26.74	23.67	5.92	6.04
0.4	24.13	25.81	5.19	4.98
0.45	22.02	22.41	4.04	5.00

They are also in Table 2 presented the values of tensile strength in bending of cement paste, depending on the moisture of specimens. Tensile strength in bending decreases with increasing w/c ratio. For water saturated specimens is decreasing of values 1 MPa. Similarly, tensile strength, in bending decreases with dried specimens of 1 MPa [7].

5. Summary

Fracture energy for water-saturated specimens decreased by 18%, depending on the water / cement ratio increased from 0.35 to 0.45. Fracture energy for water-saturated specimens decreased by 18 %, depending on the water/cement ratio increased from 0.35 to 0.45. Change of fracture energy for the dried specimens were only 5%. But the value of fracture energy for the w/c factor of 0.4 is higher than for the w/c 0.35 and 0.45.

In conclusion, the value of fracture energy of cement paste varies from 22 to 26 N/mm. The direct effect of humidity on the size of the fracture energy of cement pastes was not proved.

Acknowledgements

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